TEST OF STANFORD-LIKE N MINERALIZATION MODEL WITH FIELD-DERIVED DATA

by

C.A. Campbell[1], Y.W. Jame[1], and R. deJong[2]

[1] Agriculture Canada Research Station, Swift Current, Saskatchewan
[2] Land Resource Research Institute, Agriculture Canada, Ottawa, Ontario

A method that will provide an estimate of nitrogen-supplying power of soils, that is highly correlated to field determined data, is urgently required. One such method might be that proposed by Stanford and co-workers (Stanford and Smith 1972; Stanford et al. 1973; Stanford and Epstein 1974) and used with some success by others (Smith et al. 1977; Stanford et al. 1977; Oyanedel and Rodriguez 1977; Griffin and Laine 1983).

To use Stanford's approach requires knowledge of three soil characteristics: (i) a measure of the potentially mineralizable nitrogen (N_o); (ii) the rate of release of N_o as a function of moisture content, and (iii) rate of release as a function of temperature. Values of N_o (Campbell and Souster 1982), a moisture function (Myers et al. 1982), and temperature functions (Campbell et al. 1984) for a cross-section of Saskatchewan soils have been published. In the latter paper an N mineralization model was constructed for the Wood Mountain loam and this model was tested using results that had been obtained previously (Campbell et al. 1974) from the incubation of soil in bags both in controlled environment and buried in the field (Fig. 1). The results of the latter comparisons were quite acceptable. However, this test was based on a closed system with a minimum of wetting and drying effects and since it is well known that wet/dry events can cause marked flushes in net N mineralization (Campbell 1978), it seemed appropriate to test this model further under direct field conditions.

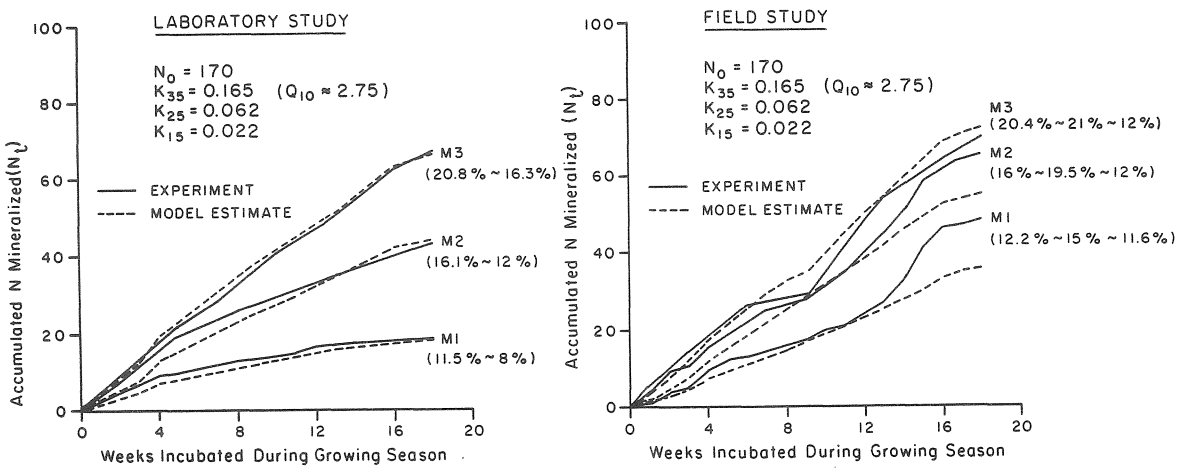

Fig. 1. Proofing the Stanford-like nitrogen mineralization model against data from a previous incubation study (Campbell et al. 1974). (The model is described in the text).

The objective of this study was to test the N mineralization model developed by Campbell et al. (1984) by using it to predict N mineralization measured under field conditions, *in situ*.

Materials and Methods

The equation developed to describe net N mineralization in the Wood Mountain loam for the top 0-7.5 cm was:

$$N_t = 170\ (1 - e^{-kt}) \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where 170 is N_o, the value of the potentially mineralizable N ($\mu g.g^{-1}$), N_t is cumulated net nitrogen mineralized ($\mu g.g^{-1}.wk^{-1}$), t = time (wk) and k, the rate constant, is the product of a temperature function and a moisture function which was:

$$k = \exp(27.33 - 8973/°K) \times (0.066M - 0.46) \quad \ldots\ldots\ldots\ldots (2)$$

In equation (2) °K = Kelvin temperature and M = the soil moisture content (% by wt).

When the model was used to predict net nitrogen mineralization based on the 0-15 cm as one entity, the N_o and k values derived for the top 15 cm of the Wood Mountain soil (in Table 1, Campbell et al. 1984) were used. These values were:

$$N_o = 125\ \mu g.g^{-1}$$

$$k = \exp(19.28 - 6696/°K) \times (0.066M - 0.46) \quad \ldots\ldots\ldots\ldots (3)$$

The N_o and k values for the 7.5-15 cm segments were derived based on the values of 0-15 cm depth (equation 3) and the 0-7.5 cm depth (equations 1, 2). The values obtained were:

$$N_o = 80\ \mu g.g^{-1}$$

$$k = \exp(16.74 - 6148/°K) \times (0.066M - 0.46) \quad \ldots\ldots\ldots\ldots (4)$$

The data used to test the model were derived from a previous experiment (Campbell & Paul 1978), which was carried out in 15-cm diam, 120-cm deep lysimeters, in the Wood Mountain loam soil. In that study there were several treatments but only the summerfallow treatment was used in this verification. There were four replicates and 26 cylinders of summerfallow soil used in this test. In two cylinders, soil temperatures were recorded hourly at several depths throughout the period of study. The depths of interest in this verification exercise were for 0-7.5, 7.5-15, and 0-15 cm. Thermocouples had been placed at 2.5-, 5.0- and 15-cm depths in two fallow cylinders. We estimated the temperature of the 0- to 7.5-cm depth as the arithmetic mean of temperatures measured at 2.5 and 5.0 cm; the temperature of the 7.5- to 15-cm depth was taken as the mean of the temperatures at 5.0- and 15-cm depth, and the temperature of the 0- to 15-cm depth was taken as the arithmetic mean of the temperatures measured at 2.5-, 5.0- and 15-cm depths.

The other 24 cylinders were destructively sampled on 6 dates starting on May 22, 1975 and ending on August 26, 1975. The cylinders were split open, the soil segmented into 2.5-cm segments from the surface to a depth of 45 cm and by 5-cm segments thereafter to the bottom (Dyck et al. 1977; Campbell et al. 1977). Soil moisture (gravimetrically) and NO_3 and exchangeable NH_4-N and bulk densities were determined on these segments.

We therefore had temperatures continuously (Fig. 2) and soil moisture (Fig. 3) and nitrate-N (Fig. 4) at six points throughout the growing season. However, we needed daily soil moisture to run the model N. For estimating daily soil moisture we used our starting soil moisture contents (May 22, 1975) together with the rainfall data and with the aid of a SPAW model (deJong & Zentner, 1985) estimated soil moistures in the various soil segments on a daily basis (Fig. 3). Because the model underestimated soil moisture by 2 to 6%, local calibration was used to match the measured soil moisture data with the predicted values (Fig. 3).

Since the exchangeable NH_4-N remained constant throughout the experiment (Campbell & Paul 1978), the net N mineralized was calculated as net change in NO_3-N per cylinder between sampling dates (see Table 1 in Campbell & Paul 1978). In estimating the net N mineralized using the model, the calculations were based on only the top 15 cm of soil. We assumed that almost all of the N mineralized in Saskatchewan soils occurs in the segment that is usually sub-

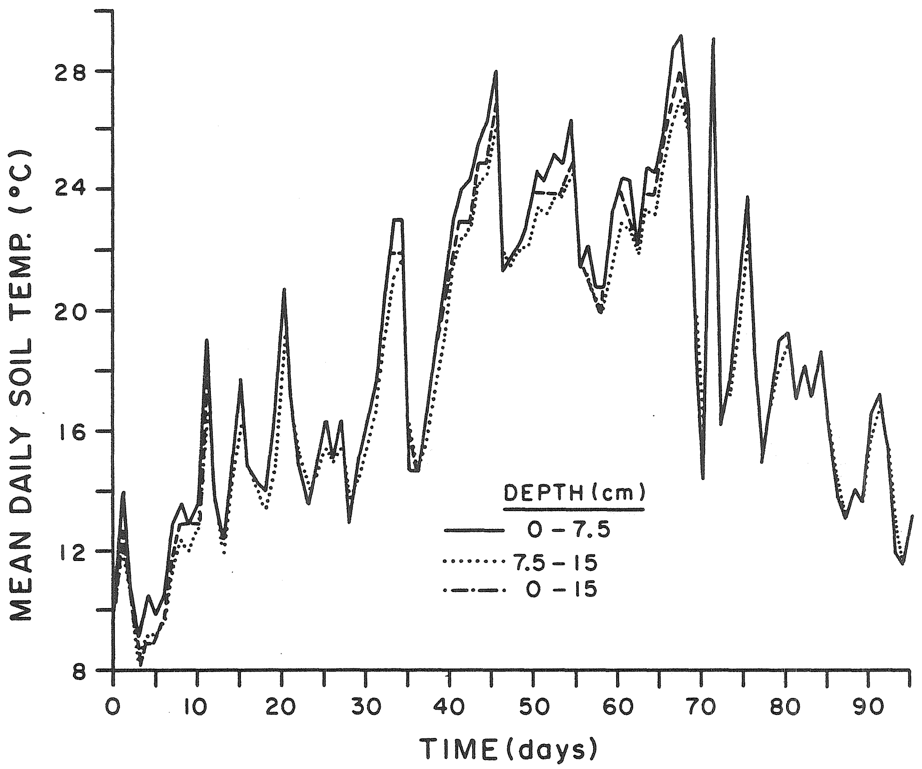

Fig. 2. Daily Temperatures in Experiment by Campbell & Paul (1978)

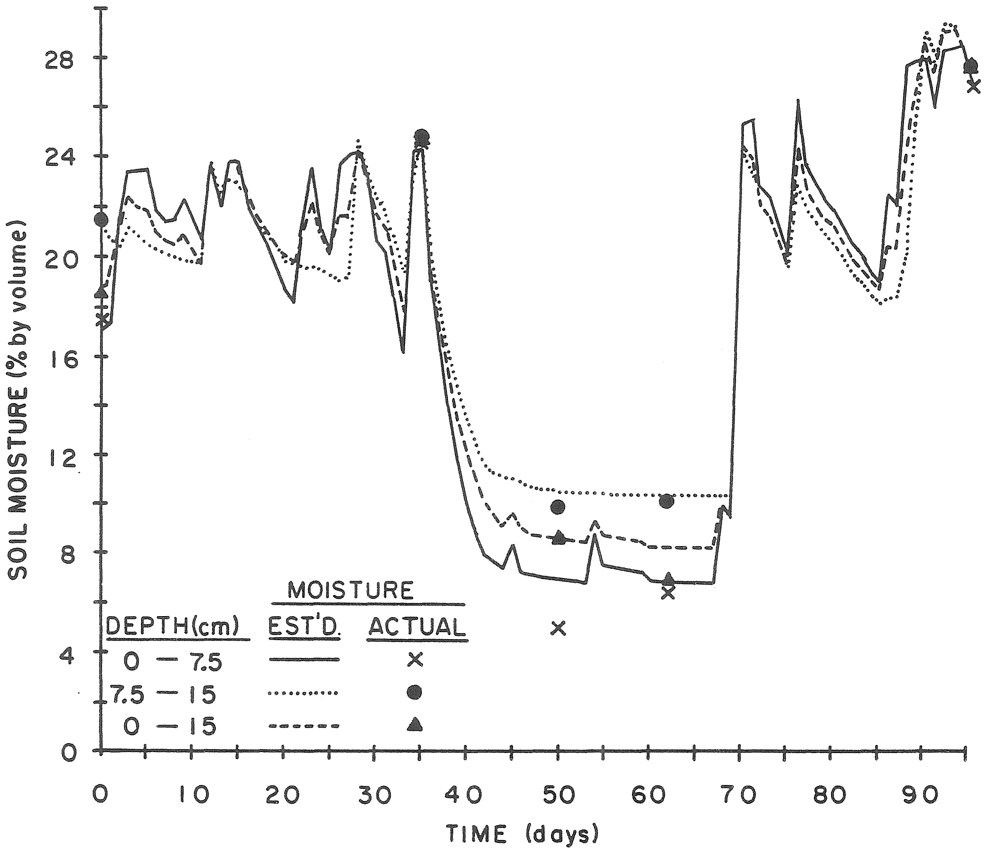

Fig. 3. Daily Soil Moistures Calculated by SPAW Model, and the Measured Soil Moisture Contents from Experiment by Campbell & Paul (1978)

ERRATA

My apologies to all who heard me speak on this subject at the Soils & Crops Workshop. We made a serious error as you can see from the attached Figure 5, which replaces Fig. 4. Unfortunately we had a mix-up in communication. The actual (measured) N in Fig. 4 was erroneously taken from the summer-fallow treatment (see Campbell & Paul, 1978, Table 1). However, the soil moistures used to generate the model calculations of net N mineralization was for the dry, zero N, cropped treatment. Thus the net N mineralization calculated by our model was matched against the wrong measured N data. We have now made the correction (Fig. 5).

The results in Fig. 5 show a very acceptable agreement between the measured and model calculated net N mineralized. Thus our discussion in the paper regarding wet/dry effects should be disregarded. We are presently working on modelling the fallow system and will keep you updated on the results at a future time.

Again our sincere apologies for leading you astray!

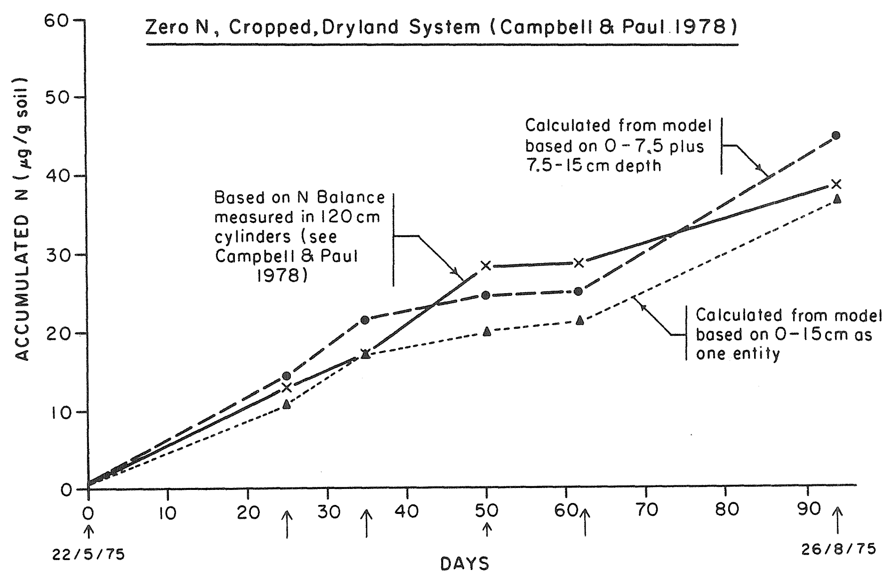

Fig. 5. Relationship Between Measured N Mineralized and N Mineralized as Calculated According to Model of Campbell et al. (1984)

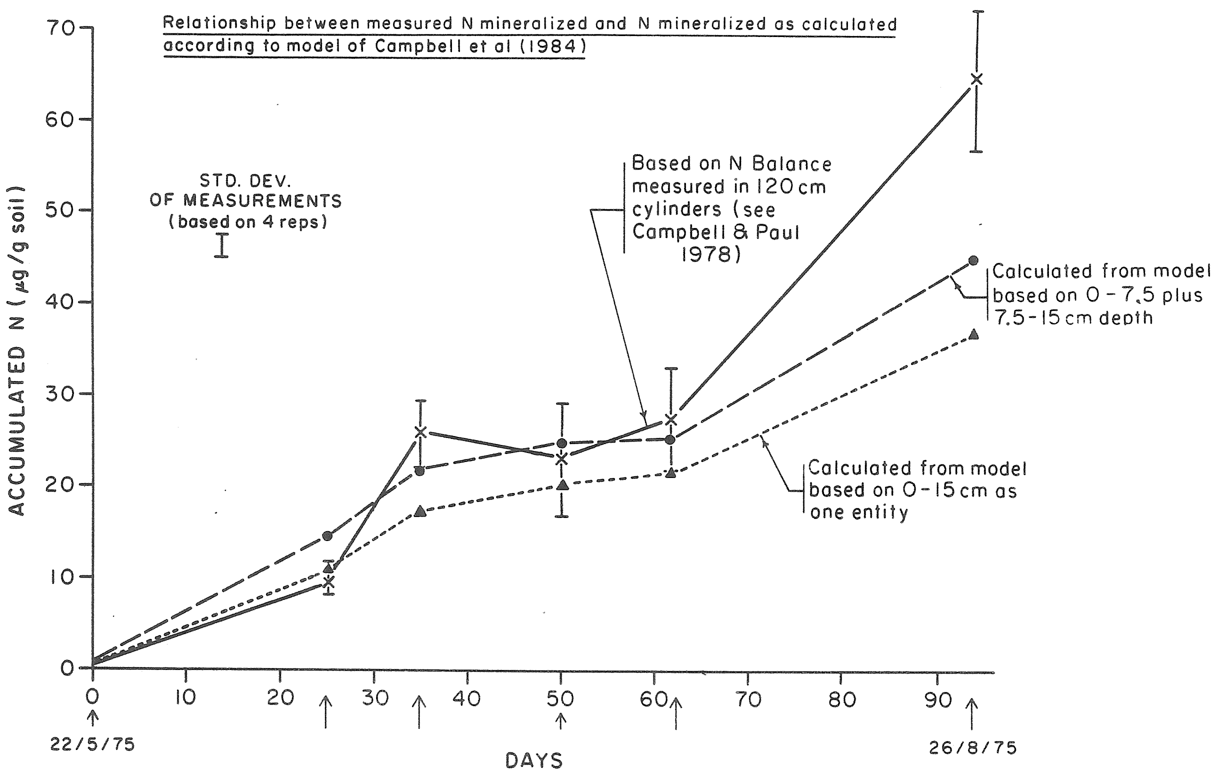

Fig. 4. Relationship Between Measured N Mineralized and N Mineralized as Calculated According to Model of Campbell et al. (1984)

jected to physical disturbance (i.e., 0-15 cm). Campbell & Biederbeck (1982) have provided evidence in support of this assumption. The calculations were made for the 0-15 cm as one entity or, as the sum of the N mineralized from the 0- to 7.5- plus 7.5- to 15-cm segments treated separately (Fig. 4 and 5). Calculations were made on a daily basis and the N mineralized during periods corresponding to those when analyses were made in the 1975 study (Campbell & Paul 1978) were estimated and compared to the measured net N mineralized (Table 1, Campbell & Paul 1978) and Fig. 4 (this paper). The values in Campbell and Paul (1978) are in mg/lysimeter. These values were converted to μg/g by multiplying by 1000 and dividing by the average weight of the top 15 cm of the fallow cylinders (i.e., 2891 g).

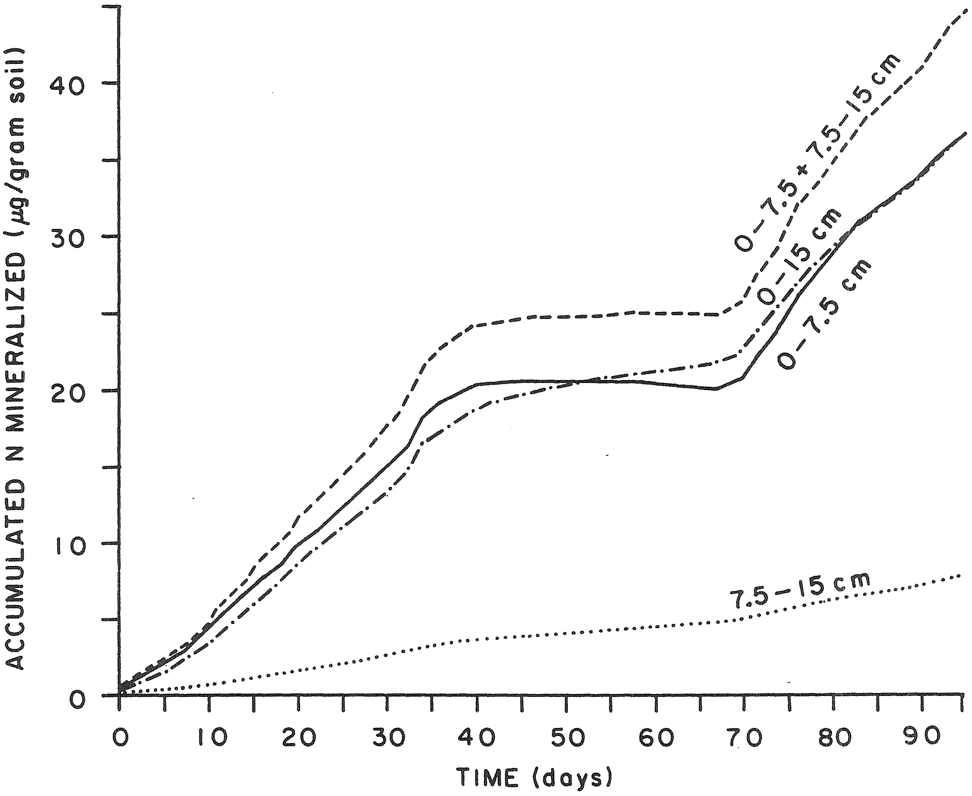

Fig. 5. Model Estimates of Daily Net N Mineralized for Various Soil Depths.

The fit was excellent up to day 60 (Fig. 4). Thereafter the model underflowed the measured results substantially. The reason for the underflow we believe to be due to flushes in net N mineralized due to wet/dry phenomenon (as described by Campbell, 1978). On July 31, heavy rain fell on a very dry soil, which suddenly increased the soil moisture from about 9% to 25% (i.e., from below wilting to field capacity) (Fig. 3). The soil had been very dry for the previous 20 days. This wetting caused a flush in mineralization of dead, N-rich microbial biomass, thus resulting in a much greater release of N than the model predicts. Thus this model does not simulate this type of wet/dry situation very well.

The failure of our model to simulate the wet/dry situation was perhaps not surprising since, in the experiment to develop the moisture function (Myers et al. 1982) constant soil moistures are used, while in the experiment to develop the temperature functions the soil is never allowed to dry much below field capacity (Campbell et al. 1984).

Thus we need to quantify the effect of sudden wetting of a dry soil on net N mineralization and to use this to modify our Stanford-like model. Birch and Friend only provided qualitative information on this phenomenon.

The agreement between the measured and calculated results (Fig. 4) was better when the calculations were based on the sum of 0-7.5 and 7.5-15 cm than on the 0-15 cm as one entity. This is because the 0-7.5 cm has a much greater microbial activity than does the 7.5-15 cm (Campbell & Biederbeck 1982) and it is unlikely that one will obtain a representative sample for all segments that make up the 0-15 cm when only a small 10-15 g subsample is used for incubation tests.

The results also show that in Saskatchewan, there is no need to use a much greater soil slice than the top 15 cm or so in estimating the net N mineralization in the laboratory. In fact, if lower depths were taken and equations developed for them under well-aerated conditions in the laboratory the results might provide erroneous overestimates of the true net N mineralization.

Conclusions

A test of a Stanford-like model for estimating net N mineralization from known temperature and soil moisture measurements was made using data derived from a summerfallowed field at Swift Current in 1975.

The model predicted the field results very well for the first 60 days of the growing season. However, when heavy rain wetted the very dry surface soil in early August, the resulting flush in net N mineralization was underestimated by the model.

It was suggested that research was required to quantify the effect of wet/dry occurrences on net N mineralization in prairie soils.

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